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ABSTRACT

In this study, six children were selected by age and were administered Piagetian tasks designed to measure their level of cognitive development against the hierarchical structuring of age/achievement posited by Jean Piaget. The task administrations are presented in detail with descriptions of the subject and the tasks, a verbatim report, and the results for each case study. Three appendixes of the preoperational, concrete-operational, and formal-operational tasks used in the report list the materials and procedure for each task in sufficient detail to permit replication. (AEA)

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Using Piagetian Tasks in Assessing Levels of Cognitive Development in Children: Six Cases

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Using Piagetian Tasks in Assessing Levels of Cognitive Development in Children: Six Cases

In an extensive body of theoretical work, Jean Piaget has attempted to account for characteristic ways that children at different stages of intellectual development have of responding to their environments. Early in his research, Piaget rejected the notion that children are miniature adults, lacking only the experience and knowledge of their adult mentors. Rather, in Piaget's view, children unconsciously strive to maintain a state of "equalibrium" with their environments by assimilating and accomodating to their experiences, in ways which differ consistently from one "stage" to the next.

In Piaget's view, between birth and the age of 14 or 15 children go through four major stages of cognitive development, each marked by certain intellectual abilities not available to them at earlier stages. These stages are the "Sensorimotor" stage, from birth to age 2, the "Preoperational" stage from ages 2 to 7, the "Concrete Operational" stage from ages 7 to 11, and the stage of "Formal Operations" at age 11 or 12 to about age 15 (Lefrancois, 1972).

In the Sensorimotor stage, from birth to about 2 years of age, children are limited to perceiving the world in the here and now. At birth and for some time thereafter, children lack language and hence any means of internal representation. Anything beyond the young child's perceptual field

effectively ceases to exist. The child's functioning is explicitly sensorimotor, in that his/her functioning involves the senses and overt behavior. Things are done, not thought about.

By the end of the Sensorimotor stage, the child has begun to communicate symbolically, through language, and has discovered that objects outside of his/her perceptual field continue to exist. He/she has also learned to coordinate separate activities, and to recognize cause and effect relationships.

A second major developmental stage is posited for ages 2 to 7, the "Preoperational" stage. Sund (1976), in "Piaget for Educators", states that children in this stage are "artificialistic and animistic;" that is, they believe that all objects are made by people (or by God, represented as a large person), and that things in their environment, the wind and rocks for example, possess psychological and logical attributes. (p. 27) They also have difficulty in distinguishing reality from fantasy. What they perceive is reality, whether they are looking at a tree or watching a television commercial. (p. 26-27) At play, children at this stage play "in parallel." They meet and play in groups, but not really together. (p. 29)

In the first two years of this stage, the "Preconceptual" period, children tend to lump all objects into a limited number of classes. For example, any adult male might be labelled "daddy." During this period, children characteristically make inferences from one specific to another, rather than from the general to the specific or from the specific to the general.

In the "Intuitive Thought" period of the Preoperational stage, roughly between the ages of 4 and 7, children begin thinking deductively and inductively, but in a manner which is very much bound by their perceptions. Although children at this developmental stage are capable of imagining what objects would look like from another person's physical point of view, they have difficulty in adopting a different mental viewpoint. The child has attained, typically, the ability to classify objects, but not to produce subclasses within larger classes, by the end of this stage. Overall, prior to about age 7, children do not reason in terms of "operations;" i.e., in terms of logical chains which can be reversed.

In the stage of "Concrete Operations," from about age 7 to 11 or 12, the child begins thinking in terms of "operations," or logical chains which he/she can manipulate. However, these operations are usually limited to concrete experience. The ability to abstract is not yet present. At this stage of development, children can sort objects into subclasses within classes, they can sort objects into series and set up correspondences between series, and they can begin to deal with numbers with some comprehension of number concepts (albeit not explicitly) like cardinality and ordinality. They also gain the cognitive operations required to deal with concepts of "conservation," as they progress through this stage. (In the Piagetian scheme, conservation deals with grasping that the mass of an object is independent of its shape, for example, and the volume of liquids is not a factor of the container they are placed in.)

Starting at about age 11, children begin moving into the stage of cognitive development called "Formal Operations." This stage is marked by the appearance of propositional thinking, the ability to reason in the abstract. The child is now able to entertain notions of "what if," to construct versions of alternate realities. By the latter part of this stage, children can comprehend allegory, such as the double entendre in "Gulliver's Travels." They are also able to solve problems presented in syllogistic form, using reflexive thinking. (Sund, 1976, p. 51) Children at this stage, between the ages of 11 and 12 to age 15, attain all of the logical operations of an adult.

There is evidence, however, that many persons do not attain the traits of formal operational thinking until well past the age of 15, if indeed they do at all (Sund, 1976, p. 75-79). It remains to be seen if this is a "problem," or simply a matter of either norming differences between Piaget's research population and other research samples, or of weaknesses in the theoretical model.

In the six cases which follow, I have attempted to assess the level of cognitive development of six children, using Piagetian tasks. The hypothesis is that the level of cognitive development of children can be predicted from their chronological ages.

The 6 Cases

Case 1: Method

Subject: The subject for this series of Piagetian tasks was a 5-year old male, the son of a university professor. He will be called "Hugo", a pseudonym, in the description which follows.

The Tasks. Ten tasks designed for the Preoperational stage of development were administered to the subject, on the assumption that they would demonstrate that the child was in the Preoperational stage. These tasks are described in Appendix I, and referred to below by title only. The relevant excerpts from my converstation with Hugo are given below. Here, and throughout the article, the subject's statements are upper case, my statements are lower case, and pauses are indicated with three dots (...).

Task 1 - Multiple Classification. I've got two boxes here, and a bunch of these paper cutouts. Some of these are rectangles, and some of them are triangles, and they're different colors and everything. What I'd like you to do is put all the things that go together into one box, and put all the rest of them in the other box. Would you do that for me? YES. ... THIS IS HARD. I know, there's so many, but I'm not in any hurry so you can take as long as you want to. (Hugo sorts them very precisely in stacks, with all rectangles and triangles of blue in one box and all rectangles and triangles of orange in the other. Since Hugo sorted them both on shape and size and color in one pass, I went on to the next task instead of asking him to try sorting them another way.)

Task 2 - Class Inclusion. This time we're going to use two apples and all these grapes. Ok, there's ten grapes and two apples. Now, in what way are these things alike? Can you tell me that? ... These apples and these grapes, how are they alike? ... THIS GRAPE IS KIND OF LIKE

THIS GRAPE. THIS GRAPE IS LIKE THIS GRAPE. And these are apples, right? RIGHT. How are grapes and apples alike? I DON'T KNOW. What do you do with grapes and apples. EAT EM. That's something they have alike, isn't it? YES. Are there more grapes here than fruit, since they're all fruit? THERE'S MORE GRAPES, CAUSE THERE'S TWO APPLES AND TEN GRAPES. SEE. (He counts them.) But it's all fruit, isn't it? Everything is fruit, the apples and the grapes? YES. Are there more grapes than fruit? ... I THINK THE GRAPES ARE MUCH MORE THAN APPLES. If I took the fruit, and you took the grapes, would you have more or would I have more? I WOULD HAVE MORE. How would you be able to prove that? YOU WOULD HAVE TWO, AND I WOULD HAVE TEN.

Task 3 - Conservation Task. This is a rubber band. See how much rubber band there is there, see how big it is. YES. (I stretch the rubber band.) Now that I've stretched it, do I have more rubber, the same amount, or less rubber? IT'S BIGGER. Would you say there's more of it, or less of it? ... THERE'S MORE OF IT. More rubber band? YES. Why would you say that there's more rubber when I stretch it? BECAUSE, LOOK. (He points at it.) Because it's longer? SURE.

Task 4 - Conservation of Substance. This time we're going to work with some clay. I'm going to make two little balls out of this clay. (I make them.) Here's one ball of clay, and here's the other one. Would you say those two are the same size? I WOULD SAY THEY ARE. I'm going to take this one here and make it into a hamburger. Like that.

We'll pretend it's a humburger anyway. (I flatten one of the balls.) Now do I have more clay in here, the same amount, or less? YOU HAVE MORE HERE. (Hugo indicates the hamburger.) Why does it look like there's more here. BECAUSE IT'S LONGER AND THINNER, AND THAT ONE'S SHORTER. THAT'S AN EASY ONE, INS'T IT? Um,hm. The other day a little boy told me that there was more here in the round ball than in this hamburger. THAT ISN'T RIGHT. THERE'S MORE IN THE BIG ONE.

Task 5 - One-to-One Correspondence. Now we're going to use some matches. I'm going to lay them out in two rows. (I lay out two straight rows of four matches each.) See, I'm taking eight matches, and I'm putting four in each row. Now, are both of these rows the same. YES. Why would you say that? CAUSE THERE'S FOUR OF THEM HERE, AND FOUR OF THEM THERE. Ok, now I'm going to fiddle with this row a little bit. ... Now, would you say there's more matches in this line, or in this one here than I changed? THIS ONE. The long one? YES. How did you figure that out? BECAUSE THERE'S ONE, TWO, THREE, FOUR IN THIS ONE, AND IN THIS ONE, YOU PUT IT A DIFFERENT WAY.

Task 6 - Structure, Transitional. Now I've got two pieces of cardboard here. This one's got an "A" on it, and this one's got a "B" on it. I'm going to line them up just like that. Now I'm going to give you this piece of paper and a pencil. I want you to draw what you see there on this piece of paper. WITH THE SQUARES? Yes. ... It doesn't have to be perfect. I JUST THINK I'LL DRAW THE A AND THE B, BUT NOT THE SQUARES. ... Do you think you could draw the squares too?

YES. Would you do that for me? (Hugo draws the squares and puts in the letters.) Now I want you to think hard about this. What would happen if I took this square right here with the "A" on it and pushed it over this way a little bit. Could you draw what that would look like? (Hugo draws this too, a bit crudely as he did the first time, but the shift to the right in the drawing is clearly there.) THAT ONE'S NOT HARD, IS IT? No, most of these are pretty easy. These are tests for fun.

Task 7 - Perception of Liquid Level. We need this bottle, half full of water. And I have a little picture here, see, that's the same bottle in the picture. Can you see where the water comes up to in the picture? YES. Now watch what happens when I move this bottle around. See, now the water's like that. When I turn the bottle upside down, see how that looks? YEAH. Now I'll turn it on its side. YEAH. See how the water moves around as I turn the bottle in all these different ways? YES. Whichever way I move it the water changes around. IT WILL FOLLOW. Yes. Now I'm going to give you this pencil, and I want you to.. see how this one is" UM,HM. This bottle is the same, so the water would go in the same way. Would you draw that in for me please? YES. (He draws in the water line accurately in the first picture.) Now, in this picture the bottle is flipped over on its side. How would you draw the water in there? LIKE THAT? Whichever way you think it should be. ... (Hugo draws the water line parallel to the bottom of the bottle, in this

and in all the rest of the diagrams.)

Task 8 - Artificialism. I have some questions I want to ask you, ok? OK. Who made the sun? I DON'T EVEN KNOW. Do you know who made the stars? NO. Who made the moon? I DON'T KNOW. You know that rocket ship that went to the moon? YES. Who made it? I DON'T KNOW. Do you think people made it? YES. What about the sun, do you think somebody made the sun? YES. Who do you think would have done that? WELL, THE SUN'S UP IN THE SKY, SO IT WAS GOD ... GOD HAD TO HAVE MADE IT. What about the stars, you reckon he made the stars too? YES. Who made waterfalls? Did you ever see a waterfall? Who makes those? EASY. THE WATER GOES RIGHT DOWN. Did somebody make them, or are they just there? THERE'S JUST A MOUNTAIN THAT GOES DOWN, AND THE WATER JUST GOES RIGHT DOWN. Did you ever go to the ocean and see the waves? YES. What do you think makes the waves on the ocean? I DON'T KNOW. What about lakes? Do you have any idea where lakes come from? YEAH, FROM THE SEA. I LEARNED THAT IN SCHOOL.

Task 9 - Construction of 2-Dimensional Space. For this, we'll need a paper and pencil, and a pair of scissors, and a ruler, and some string. These are all for you to use if you want to use them. MY DADDY USED TO HAVE ONE OF THESE. A ruler like that? YES, BUT INSTEAD IT BROKE. Oh. KNOW WHO BROKE IT? ... ME. I have two pieces of paper here. This one's for you to draw on. On this other piece of paper, I put a dot right there. I want to see if you can put a dot on this

piece of paper in the same place where that dot is there. You can use any of these things you want to. HOW COULD I USE A STRING? Well, whatever. (He places the dot by eyeballing the original one.) Why did you put the dot right there? CAUSE IT LOOKS THE MORE. Looks like it's in about the same place, huh? YEAH. Ok.

Task 10 - Seriation. I have a deck of cards here, with stick people on them, and the cards are in all these different sizes. Here's one here (the largest) and here's another one I'm going to put way over here (the smallest). I want you to take the rest of these cards and put them in order, so they look like they go from there to there. Any way you want to do it. ... All those cards are different, aren't they. YEAH. I THINK I'LL HAVE TO MAKE ANOTHER ROW. ... Did you hear the thunder last night? NO, I WAS DEEP ASLEEP. ... BESIDES, I COULDN'T EVEN SLEEP. Why not? THUNDER. I wonder what makes the thunder? Do you know what makes the thunder? ARE YOU ASKING ME THOSE QUESTIONS AGAIN? Yes, I was just wondering about that. Do you think the thunder is alive? NO. ... IT SOUNDS LIKE A LION, DOESN'T IT? (This conversation takes place as Hugo is sorting out the cards. He groups the cards into three sets of similar stick figures, roughly by size.) Are you all done? YES. How did you figure out how to do that? I DECIDED TO MAKE THE PERSONS THAT ARE THE SAME.. THAT ARE LIKE THESE.. You mean these persons looked a little different to you than these persons over here? YES. Ok. CAUSE LOOK HOW BIG THESE ARE. Yes.

Results for Case 1

Hugo had no problem with the Multiple Classification task, demonstrating that he could group things in more than one way. His performance was solidly preoperational. In the Class Inclusion task, he could not differentiate between the way I was using the class "fruit" and the subclass "grapes." Here, his performance was typical of children even up to age 7 or 8. On the Conservation task with the rubber band, he failed to conserve, again a preoperational response. On the Conservation of Substance task, with the clay, he again failed to conserve, as I expected. On the One-to-One Correspondence task, he performed preoperationally, even through he actually counted out the matches in each row. In the Structure-Transitional task, he performed as well as most 7-year olds would, still preoperational. On the Perception of Liquid Level task, his performance was appropriate to that of "intuitive" thinkers in the preoperational stage. In the Artificialism task, he made an interesting division between stellar events, attributing those to God, and earthly events like waterfalls, attributing those to natural forces. His performance here was approaching that of Concrete-Operational level children. On the Construction of 2-Dimensional Space task, his performance was like that of most early preoperational children, since he made no attempt to measure. On the final task, Seriation, Hugo made a rough grouping, but did not take the cue of the various-sized cards. My conclusion from all of this is that Hugo is at the Preoperational level, as I would predict from his age.

Case 2: Method

Subject: The subject for this series of Piagetian tasks was a 6-year old female from a lower socio-economic background. She will be called "Cynthia" in the following description.

The Tasks. Ten tasks designed for the Preoperational stage of development were administered, to test the assumption the Cynthia was functioning at the Preoperational level. These tasks are described in Appendix I.

Task 1 - Multiple Classification. I've got these two boxes, and I've got all these different things. I've got some blue things and orange things here, different shapes and sizes and everything. What I'd like you to do is put all the ones that you think go together in one box, and put the rest of them in the other box. LIKE THIS, ALL THE COLORS IN ONE..? Whatever way you want to do it. (Cynthia puts all the objects into one box, carefully grouped by size and shape.) Which ones are you going to put in the other box now, there aren't any left? (This time, Cynthia sorts all the rectangles into the other box, and leaves all the triangles in the first box.) Why did you put them together like that, Cynthia? (She shrugs.) Just felt like it, huh. Can you think of another way to sort them out? BY COLORS. Ok, do you want to try that? (Cynthia sorts them into the two boxes, by color.)

Task 2 - Class Inclusion. (I put two apples and ten grapes in a row in the table.) What do you call these? APPLES. And what do you call these? GRAPES. Is there some way that they're alike? What's

the same about them? ... Is there some name you would give all of them? ... You could call them fruit. YES. Do you know about that word "fruit?" Apples are fruit and grapes are fruit. YES. What's going to happen if I take the fruit and you take the grapes? Who's gonna have more? YOU TAKE THE GRAPES AND I TAKE THE APPLES? No, I'll take the fruit, and you take the grapes. ME, I'LL HAVE MORE. How did you figure that out? CAUSE THERE'S MORE GRAPES THAN THERE IS FRUIT. Ok, how would you prove which one of us had more? BY THE GRAPES, AND YOU SHOW ME THE FRUIT.

Task 3 - Conservation Task. I have this rubber band. (I hand it to her.) See, it's just a regular rubber band. Now let me show you something about this rubber band. See how big it is? (I hold it slack, then stretch it.) Now do I have the same amount of rubber that I had before? NO. What's different about it? CAUSE IT'S BIGGER. (I repeat the experiment, with the same results.)

Task 4 - Conservation of Substance. I've got some clay here. (I form two balls out of the clay.) I'm trying to get these the same size. Do those look like they're about the same size to you" NO. Which one's bigger, I'll make it smaller. (She points it out.) Ok, I'll make it smaller. ... Are they the same size now? YEAH. Now watch this, I'm going to take this one and make it into a hot dog. (I roll one ball into a cylinder.) Now, do I have more clay here (indicating the "hot dog.") than I did when I started, do I have less clay, or do I have the same amount of clay? IT'S NOT THE SAME

AMOUNT. Which one has more clay in it? (Cynthia points to the cylinder.) The long one has more in it? (She nods yes.) The other day a little boy told me that there was more clay in the ball. What would you tell that little boy? THAT IT ISN'T. How would you explain that to him? I'D SAY, SEE, THE BALL DIDN'T HAVE MORE CLAY, THAT ONE THAT HE ROLLED HAD MORE CLAY.

Task 5 - One-to-One Correspondence. Now we're going to do a thing with matchsticks. I'm going to make two rows of matches, with four matches in each row. (I make two straight rows.) There's one line, and here's the other one. Now, would you say they are about the same? YES. Why would you say they're the same, this row and this row here? SEE, BECAUSE THEY'RE BOTH STRAIGHT, THEY'RE NOT WIGGLY OR NOTHING LIKE THAT, THEY'RE JUST STRAIGHT AND STILL. What about the number of matches I have in each row, is that about the same too? FOUR AND FOUR. Now let's do something a little different. (I change one of the straight lines into a different shape.) Now, which row has more matches in it? (She points to the long row.) This one does? YES. So, I took these matches and laid them out in a straight row, and I took these and made this out of them. Why would you say that one (the long row) has more matches in it? WELL, I SAID THIS ONE (the long row) HAD MORE MATCHES, BUT IT'S STILL FOUR AND FOUR. Oh, so they have the same number of matches? YES.

Task 6 - Structure, Transitional. Now I've got these two squares here. One of them has this letter "A" on it, and the other has a letter

"B." I'm going to put them so they're one right above the other. I'll get you a piece of paper and a pencil. What I'd like you to do is draw on the paper what you see right there. JUST DRAW A STRAIGHT LINE LIKE THIS? Well, draw a picture of this thing I made here. (She draws in quite accurately.) Now I want you to imagine in your head what it would look like if I took this top square here, and slid it over a little bit this way. Can you draw me a picture of what it would look like if I did that? LIKE THIS? (She pushes the top square over to the right.) Yes, like that. (I slide it back again.) Ok, just imagine in your mind what it would look like if I did that, and draw a picture of it. (Again, she draws the figure quite accurately.) Would you put the letters in too? (She does.) Now why did you draw it like that? (She slides it over to show me.) Fine. Let me put your name on this so I can save it.

Task 7 - Perception of Liquid Level. Here we have a bottle with some water in it. It's half full of water. Now I want you to watch the top of the water as I move the jar around, see what it does. (I tilt the bottle in various positions.) See how the water changes as I move the jar around? When it's upside down, see where it is? And when it's right side up, it's like that. Sideways. ... Tilted. ... All those different ways for one bottle of water. Now I have this diagram I want you to fill in for me. I did the first one.. see, here's the bottle, and here's the water right here. See where the water is?

On this bottle, I want you to draw in the water for me, where the water line would be. (She draws it.) Now, in your mind figure out where the water would be in these other bottles, and draw those in too. (She draws the next two accurately, the fifth and seventh parallel to the lower side of the tilted bottle, and the sixth parallel to the bottom of the bottle.) Could I save this drawing too. YOU CAN SAVE ALL OF THEM YOU WANT.

Task 8 - Artificialism. I have some questions I want to ask you. Who made the sun? JESUS. Who made the stars? JESUS. How about the moon, who made the moon? ... JESUS. Do you remember that rocket that went to the moon? ... Remember when the men went up there and walked around on it? (She shakes her head no.) Well, that was done when you were really little. Who would make a rocket ship like that? JESUS. What about waterfalls and lakes and stuff like that? JESUS. What about waves on the ocean? JESUS.

Task 9 - Construction of 2-Dimensional Space. We're going to draw some more. I've got these two pieces of paper, and I'm going to put a dot right here on this one. ... You can use these things if you want to. Here's a piece of string, a pair of scissors, and a ruler. And here's a pencil. I want you to figure out some way that you can put a dot one this blank sheet of paper just exactly where the one is on this piece of paper. Can you figure out a way to do that? (Cynthia measures from the dot to the edge of the paper with her fingerwidths, then performs the same measurement on the blank sheet. She

guesses the distance from the top of the sheet, and draws in the dot.)

Task 10 - Seriation. I have some cards here. See how they're all different. I'm going to put this one down, and this one down. (I put the largest card to her right, and the smallest to her left.) I want you to arrange these other ones so they go from here to here the way you think they should go. LIKE BIG, LIKE LITTLE? Any way you think it ought to be done. (Cynthia carefully arranges the cards so larger and smaller cards alternate.) How did you figure out how to do that? BIG, LITTLE, BIG, LITTLE, BIG, LITTLE. So you did them like that. Ok. You have a big one and a little one, and big one and a little one, right across the line. YES.

Results for Case 2

Cynthia did the Multiple Classification task several different ways, indicating ability in this aspect of cognitive development appropriate to preoperational thinking. On the Class Inclusion task, she failed to differentiate between the subclass "apple" and the larger class "fruit," again performing typically for a preoperational person. On the Conservation task with the rubber band, she indicated that the stretched rubber band had more rubber in it; that is, she failed to conserve mass, again typical of preoperational children. On the Conservation of Substance, she again failed to conserve, as I expected. On the One-to-One Correspondence task, however, she performed at the Concrete-Operational level, unlike Hugo in case 1. Also on the Structure, Transitional task she had no problem, indicating that she

was in a transitional stage to Concrete-Operational thinking. On the Perception of Liquid Level task, she drew in half of the water levels as would most children of age 9 or 10, and half of them obliquely toward the opening of the bottle as do children in later Preoperational thinking, again indicating a transitional stage to Concrete-Operational. In the Artificialism task, her invariable response of "Jesus" to all of the questions indicated to me that she might have been answering in a formalistic manner, without thinking about it. Her responses were very rapid, reinforcing this interpretation. This task, as I see it, was inconclusive in this case. On the Construction of 2-Dimensional Space task, she made an attempt to measure, but only in one direction instead of two. This response is typical of later preoperational children. On the Seriation task, she grouped the cards in twos, indicating performance at the Preoperational level. My overall assessment of Cynthia is that she is in the Preoperational stage, already beginning a transition to the Concrete-Operational stage. In this case, as in Hugo's case, my hypothesis that the level of cognitive development can be predicted from chronological age was borne out.

Case 3: Method

Subject. The subject was an 8-year old female, the daughter of a university professor. She will be called "Jane" below.

The Tasks. Eight tasks designed for the Concrete-Operational stage of development were administered, to test the assumption that Jane was functioning at the Concrete-Operational level. The tasks are described

in Appendix II.

Task 1 - Seriation. The first thing is, I have these cards that I made, that have these stick figures on them. I'm going to put down this one, and this one (I place the largest card to her right and the smallest to her left) and mix these other ones up a little bit. What I'd like for you to do is arrange these other cards in order. We've got these two down already. Arrange these others in a way you think they ought to go. (Jane arranges the cards from small to large, with one card out of sequence by one position.) Are you all done? YES. How did you figure out how to do that, Jane? IT GOES FROM SMALL TO BIG. Ok.

Task 2 - Correspondence. Now we're going to use some pennies, this big cup, and this little glass. I'm going to take one penny and put it in here, take one and put it in here. (This continues, until 12 pennies are counted into each container, counted out one by one as I go.) I want you to look at these two containers, the big one and the little one. Which one would you say has.. would you say that this one has more pennies in it than that one, the same number of pennies, or fewer pennies? How does it look to you? Which one has more pennies in it, or are they both the same? THE BIG ONE DOES. The big one has more pennies in it? YES.

Task 3 - Horizontal and Vertical Orientation. I've got these two little people and these paper clips. This one is a teacher, and this one is a student. What I need for you to do is fix these paper clips

up so they're halfway between the teacher and the student. THIS WAY? Any way you want to, just so they're the same distance from the teacher and the student. (Jane places one paper clip vertically centered on the teacher card.) I need each one halfway between the teacher and the student. (Jane puts a clip vertically centered on the student card.) Do you know what I mean by halfway between the teacher and the student? (I point to a spot on the table halfway between the two cards.) YES. (Jane puts a clip on each of the cards, this time centered horizontally.) Ok, that's one way to do it. This is halfway from here to here, and this is halfway from here to here. Is that the way you figured it out? YES.

Task 4 - Conservation of Area. For this one we're going to use these rubber erasers. I've got eight erasers. THAT'S HOW OLD I AM. Ok. Now I'm taking four and I'm arranging them like this (I make a square), and I'm going to take four more and arrange them like this (I arrange them in a row). I've got two different arrangements. There's four erasers here, and there's four here. Now is it further around here, or further around here, or is it the same? IT'S FURTHER AROUND THIS ONE. (Jane indicates the long row.) How did you figure that out? IT'S LONGER, AND THAT ONE'S SHORTER. Ok. If you had to explain it to a child that was having a problem with it, how would you explain it? THIS ONE WOULD BE A LITTLE LONGER, AND THIS ONE WOULD BE A LITTLE SHORTER.

Task 5 - Conservation of Displacement Volume. (I put water into two tumblers, and adjust the level until Jane and I agree the height in

the two containers is the same.) I'm going to take this marker and mark on here right where the top of the water is. And I'm going to mark this one right where the water is. Now I'm going to make two balls of clay the same size. ... Ok, would you say that those two balls are about the same size? NO. ... Ok, would you say that those two balls are about the same size now? THIS ONE'S BIGGER. (I compress it some more.) Are they about the same size now? YEAH. Now, I'm going to take this one and turn it into a hamburger. I'm not going to put any mustard on it, though. I'm just going to flatten it out. ... Now, we've got two pieces of clay. What do you think will happen to that water if I put this ball of clay into it? IT'S GOING TO GET .. TO GET SOME MORE. Ok, mark on that cup where you think the water is going to go to. (She marks it. We put the ball of clay in, and the water goes pretty close to the mark.) Now we've got this other one here, and I want you to mark on this cup where you think the water is going to go. (She marks it at the same height as she did the first cup.) Did you make it the same as the other one, is that how you did it? YES. (We immerse the "hamburger.") Did you figure this was going to go up a little more than that one, or be about the same. ABOUT THE SAME. Ok, how did you figure that out? WELL, THEY BOTH WEIGH THE SAME, AND WHEN YOU PUT THEM IN THERE, THEY WOULD BOTH BE THE SAME. THEY STARTED OUT THE SAME SIZE.

Task 6 - Conservation of Substance. Now I've got some popcorn here. This is popped, and this is unpopped. Now look at this popcorn here. Is there more corn after the corn is popped, or before

it's popped? AFTER. How did you figure that out? I DON'T REALLY KNOW. When you look at it, what is it that tells you there's more corn here than there is here? PROBABLY WHEN IT POPS, THEY GET TOGETHER AND THAT POPCORN CAN GET INSIDE THEM.. UM, THEY COULD STICK TOGETHER. So the little ones stick together and make a big one? Is that how that works? WELL, IT COULD. Can you think of some other way it could work? Let's say this is this piece of corn before it popped, and this is the same piece of corn after it popped. Now how would that work? IT GETS HOT, AND WHEN IT GETS HOT IN THE POPPER, THEY JUMP AROUND. INSIDE, THEY OPEN AND THERE'S THIS STUFF INSIDE IT. THERE STUFF INSIDE THERE, AND IT COMES OUT WHEN IN POPS. So, do I have more corn after it pops than before it pops? YES.

Task 7 - PART-WHOLE RELATIONSHIP. Where is your town located? ... Is it in a state? YES. What state is it? TEXAS. Is your town bigger than Texas, is it smaller than Texas, or is it the same size as Texas? THE SAME SIZE AS TEXAS. Your town is the same size as Texas? NO, BIGGER. Which is bigger? THE TOWN, Ok. Are the people who live in your town, do they also live in Texas? YES. Where do the people in Texas live? IN THE TOWN OF TEXAS. Do you know the difference between a town and a state? WELL, I THINK A TOWN IS BIGGER THAN A STATE. I'm going to draw a little picture of Texas. Let's say this is Texas. Where would your town be? (Jane draws a line bisecting the state horizontally.) IN THIS PART. (She points to the upper half.)

Can you point to it more exactly, where your town is? (She marks it with a dot, quite accurately.) RIGHT HERE. The other day a little boy told me that people from Texarkana are also Texans. Is that true? Would somebody from Texarkana be a Texan? YES. If somebody was from San Angelo in Texas, would they be a San Angeloan or a Texan? A SAN ANGELOAN. Could they be a Texan and a San Angeloan at the same time. NO. How does that work? THEY COULD BE BOTH.

Task 8 - Physical Causality, Animism, Artificialism. What are stars? ... KIND OF A SUN. ARE THEY BIGGER THAN THE SUN? I'm not sure, I just wanted you to explain it to me. Where do they come from? FROM THE EARTH. How were they made? THAT'S A HARD QUESTION. What do you think? UM, FROM THE SUN. STARS ARE MADE FROM THE SUN. Do you think the sun made them, or the earth did, or what? THE SUN MADE THEM. Have you ever been to a great big lake? YES. What did it look like? IT'S BIG, AND IT HAS WAVES. How was it made? FROM WATER. Ok, what's a lake made out of, anything besides water? MUD, SAND. The last lake you went to, do you know what that lake will look like in 100 years? I DON'T KNOW.. DIFFERENT. How will it be different? THEY COULD CHANGE IT AROUND. Who could change it around? PEOPLE, THAT OWN IT. Where did the lakes come from, then? WATER.. WELL, FROM RAIN, THAT CAME FROM THE EARTH, UNDERGROUND. What about wind, where does that come from? I DON'T REALLY KNOW. When you're out playing and you feel a breeze, where is that coming from? FROM THE SKY. When it isn't there, where

is it? SOMEWHERE ELSE. Where did it come from in the first place? FROM THE EARTH. How did it get up in the sky? NOT FROM THE EARTH, FROM THE SKY. Is the wind alive? NO. It's not alive? YES. Why do you think it's not alive? IT'S NOT A PERSON, IS IT? I don't think so. What about things that float in the water. (I put a popped kernel of popcorn into a water glass.) Why do you reckon that floats in the water? CAUSE IT'S LIGHT. Would it sink? NO. (I put a penny in the water.) Why didn't that penny float? BECAUSE IT'S HEAVIER THAN THE POPCORN.

Results for Case 3

Jane did the Seriation task with no problem, indicating that she had grasped the principles of cardinality and ordinality in numbering. On the Correspondence task, she gave a preoperational response when she indicated that there were more pennies in the larger container. In doing the Horizontal and Vertical Orientation, she devised a solution I did not expect in placing the paper clips centered in the middle of each figure rather than between the two figures. In looking back at her reactions and at our conversation, I think she literally followed my instructions. Overall, I think she did grasp the principle of horizontal and vertical orientation, a Concrete-Operational level task. On the Conservation of Area task, Jane gave the correct answer, but she did not appear to reach her answer by actually counting the number of sides of the two figures. I got the impression that she was reacting directly to the perceptual clue of length, and this may be regarded as a preoperational response. On the Conservation of Displacement Volume task, she quickly reached the correct answer on a problem

that many children cannot solve correctly until age 12 or older. Her rationale for her answer showed a clear grasp of this conservation problem. On the Conservation of Substance task, Jane initially reacted directly to the perceptual clues of the situation and stated that the popped popcorn had more corn in it. On further questioning, however, she revised her answer, but then concluded that the popped corn had more corn in it. On this task, her performance was preoperational. On the Whole-Part Relationship task, I found her responses ambiguous, sometimes appearing to be correctly reasoned and sometimes not. I'm not sure if her performance on this task indicated a preoperational or a concrete-operational response. On the Physical Causality, Animism, Artificialism task, her responses indicated at least a transition from the Preoperational stage to the Concrete-Operational stage. Stellar events were attributed to natural forces, as was wind. However, she regarded lakes as subject to long-term change through the workings of their owners. I would have liked to have questioned her further on this, to see if she had had lakes presented to her by adults as man-made phenomena.

Overall, I conclude from the results of the tasks that Jane is in a transitional stage between the Preoperational stage and the Concrete-Operational stage, with most of the transition accomplished. I was puzzled by the facility she demonstrated in the Conservation of Displacement Volume task, one which can be difficult for even early Formal Operational children. I would have predicted from her age (8)

that she would have been solidly into the Concrete-Operational stage, and this prediction was not fully borne out by the evidence.

Case 4: Method

Subject. The Subject was an 11-year old male from a lower socio-economic background. He will be called "Bill" below.

The Tasks. Initially, eight tasks designed for the Concrete-Operational stage were administered, to test the assumption that Bill was functioning at the Concrete-Operational stage. The tasks are described in Appendix II. Because of the response Bill made on these tasks, three tasks designed for the Formal Operational stage were also administered, and these tasks are described in Appendix III.

Task 1 - Seriation. I've got these cards. There's one. ... and there's one ... and here's all the rest of them. Now, what I'd like you to do, Bill, is to arrange them so they're in order, any way you think they ought to be arranged. (Bill rapidly arranged the cards into order by size.) Why did you arrange them like that? BY SIZE. All right.

Task 2 - Correspondence. A big glass, and a little glass, and here's a bunch of pennies. I'm going to put one penny in this big glass, and one in this small one here. Put one in the big one, and one in the small one. (This continues, until 12 coins have been placed into each container.) Now, do I have more pennies in here or in here? EQUAL. Is it the same? YES. How did you figure that out? BECAUSE EVERY TIME YOU PUT ONE IN HERE,

YOU PUT ONE IN HERE TOO.

Task 3 - Horizontal and Vertical Orientation. I've got these two little guys here. (I lay out the two stick figure cards.) This is a teacher, and this is a student. And I've got some paper clips. What I want you to do is take these clips and arrange them somehow so they're halfway between the teacher and the student. LIKE IN A STACK? Any way you want to. (Bill arranges the clips in a stack midway between the two cards.) Is there some other way you can do that? Does anything come to mind? (Bill arranges the paper clips in a straight line, each clip equidistant from the two stick figures.)

Task 4 - Conservation of Area. This time we're going to take these erasers.. I'm going to take four of them and put them like this. (I arrange them into a square.) And take four more, and put them like this. (I arrange them in a straight row.) Now, is it further around this square as around that row, or is it the same, or what? THE SAME. They look the same to you? How did you figure that out? CAUSE SEE THEY'RE ALL THE SAME SIZES AND JUST ABOUT ANY WAY YOU'RE GOING TO ARRANGE THEM, THEY'LL STILL BE THE SAME.

Task 5 - Conservation of Displacement Volume. What I want to do is make two balls of clay the same size. (I roll out two balls of clay.) Do these look about the same size to you or not? THEY'RE THE SAME. (I fill two glasses each 3/4 full of water.) I'm going to mark this water level, where it's at right now. (I take a marker and mark the water level on both containers.) Now, we've got these

two balls of clay about the same size. I'm going to take this one and flatten it down, make a pancake out of it. Now I want you to figure out what's going to happen to the water level when we put this round ball in that glass. Mark where you think the water is going to go. ... Go ahead and put that one in, and let's see where it goes. (The level comes out almost exactly as marked.) Ok, let's try it with this one here. Mark where you think the water's going to go. (Bill marks the second container at precisely the save level as he did the first.) Let's toss it in there and see what it does. ... How did you figure that out? CAUSE THERE'S THE SAME MASS OF CLAY. The same mass of clay? RIGHT.

Task 6 - Conservation of Substance. (I place three unpopped and three popped kernels of popcorn before Bill.) Let's see, I've got some popped, and some unpopped. These kernels are about the same size, and these popped kernels are about the same size. Let's assume that these unpopped kernels are exactly the same size, and these popped kernels are too. Is there more popcorn before it's popped, or after it's popped? AFTER. How did you figure that out? BECAUSE IT BUSTS OPEN. So there's more corn in here (indicating the popped corn) than there is in here (the unpopped corn)? THERE'S MORE CORN IN.. WELL, IT WOULD BE ABOUT EQUAL. Would it? BECAUSE WHEN THAT BUSTS OPEN, IT COMES OUT TO THAT. So would you say there's more corn in the popped one, or in the unpopped one, or how would you figure it out? EQUAL. They're about equal? How did that work again?

BECAUSE, SEE, WHEN YOU POPPED THIS ONE, IT BUSTS OPEN, AND THIS IS INSIDE OF IT.

Task 7 - Part-Whole Relationship. I have some questions I want to ask you. Where is your town located? IN TEXAS. Is the state your town is in bigger than the town, is it smaller than the town, or is it the same size as the town? BIGGER. The state is bigger than the town? YES. Are the people in your town also people in the state? YES. Where do the people in your state live? IN TEXAS. (I sketch a rough outline map of Texas.) Put in where you think Bowie County would be. (Bill draws it in about the right size and location.) Are the people in Bowie County called by the name of the state, or by the name of the county? THE COUNTY. What are they called? BY THEIR NAMES. CITIZENS. What about.. would you call people in the county Texans or Bowieans? TEXANS. Why? BECAUSE IT'S IN THE STATE OF TEXAS.

Task 8 - Physical Causality, Animism, Artificialism. What are stars? UM, LIT ROCKS.. ROCKS THAT REFLECT THE MOONLIGHT. Ok, where do they come from? GOD MADE EM. Ok, God made the stars, and they're like rocks that reflect the moonlight? WELL, WHEN GOD MADE THE EARTH THERE WERE, LIKE, ASTEROIDS, AND THEY ALL COME TOGETHER, AND THEN THEY BEGAN REFLECTING SUNLIGHT AND WERE CALLED THE STARS. Ok. When was the last time you saw a big lake? YESTERDAY. What did it look like? WATER.. TREES.. IT LOOKED LIKE A BIG MIRROR. How do you suppose the lake got there? WHEN IT RAINED, IT FORMED. WHEN GOD MADE THE EARTH, THERE WAS WATER, AND INSTEAD OF JUST STAYING WATER, IT FORMED IN

PUDDLES. What's a lake made out of? WATER AND SAND. That lake you went to yesterday, what will it look like in 100 years? IT'LL STILL BE THERE, JUST LIKE IT WAS. What about wind, where does the wind come from? WHEN, SAY LIKE YOU'RE OUT PLAYING OR SOMETHING, AND THE WIND STARTS COMING UP.. THEY ALWAYS SAID IT COMES FROM THE NORTH, BUT IT'S JUST A BIG GUST OF AIR. When it isn't here, where is it? SOMEWHERE ELSE. Is it always blowing? YES. Where did it come from in the first place, do you suppose? I GUESS SOME AIR JUST STARTED CIRCULATING, AND IT STARTED BLOWING REAL HARD. What do you mean by "air circulating?" WELL, WHEN HOT AIR RISES, THEN IT COMES DOWN, IT COOLS, AND IT STARTS BLOWING. How does the wind feel when it hits us? LIKE IT'S PUSHING US. How did you figure all that out about the wind? FROM.. WELL, FROM SCHOOL, WE LEARNED ABOUT WIND. What about things that float? What floats in the water? AIR. Does that float in the water? NO, STUFF THAT HAS AIR IN IT.. BECAUSE AIR IS LIGHTER THAN WATER. Do you think things like to float, or do they just float." THEY JUST FLOAT. Why do they sink? THE WATER GETS IN EM, AND THEY GO DOWN.

Task 9 - Syllogism (Formal Operational, see Appendix III). I have some more questions for you. Just suppose all teachers have purple hair. (Bill looks puzzled, but goes along with the supposition.) And suppose there's somebody named John that has purple hair. Therefore, John is a teacher. Is that always true? NO. When would it be true? YOU SAID ONLY THE TEACHERS HAVE PURPLE HAIR. Well,

all teachers have purple hair. NO. Do you mean that John might have purple hair and still not be a teacher, is that true? NO, YOU SAID THAT ALL TEACHERS HAVE PURPLE HAIR, SO THAT MEANS HE IS A TEACHER. John has purple hair, so he must be a teacher, is that it? YES. Here's another one for you. Beetles eat elephants. I've got a bug in my pocket that ate an elephant. Would that bug have to be a beetle? NO.. YES, IT WOULD. Let's say beetles eat only elephants and hamburgers, that's all they eat. And I've got a real fat beetle in my pocket. Would it be true that that beetle in my pocket either ate an elephant or a hamburger? YES. Why would that be true? BECAUSE HE WOULD HAVE TO EAT SOMETHING TO GET THAT BIG, AND YOU SAID HE ONLY EATS HAMBURGERS OR ELEPHANTS. Bob is taller than Randolph, and John is shorter than Randolph. Therefore, Bob must be ____ than John. Is he taller, or shorter, or the same? TALLER. Bob must be taller than John? YES.

Task 10 - Verbal Deductive Reasoning (Formal Operational, see Appendix III. Here's another one. Bob has lighter hair than John. John has darker hair than Bruce. What is Bruce to Bob? (Bill reads the item.) How do you work that one out? BOB HAS LIGHTER HAIR THAN BRUCE.

Task 11 - Hypothetical Reasoning (Formal Operational, see Appendix III. Did you ever shoot any pool? YES. If this is a cue ball (I point to the diagram) and you want to sink that ball marked X there into the side pocket, either one of them, how would you hit it?

Just draw it right on there. (He sketches the shot accurately.) How about this one? (He sketches the second diagram in correctly.) How about this one here? (He does this one correctly too.) If you were trying to explain this to some kid who didn't know anything about pool, is there some kind of rule you could use to explain how you figured that out? WHEN YOU HIT A BALL, SEE, THESE ARE PADS. SO IT WOULD HIT THE PADS AND IT'S GOING TO GO.. LIKE IF YOU SHOOT IT AND IT HITS HERE, IT'S GOING TO BOUNCE OFF HOWEVER IT GOES IN, IT'S GOING TO BOUNCE OFF IN THE OTHER DIRECTION, AT THE SAME ANGLE.

Results for Case 4

Bill had no problem with the Seriation task, indicating a mastery of number concepts. On the Correspondence task, he demonstrated the attainment of the concrete-operational ability of doing one-to-one correspondence. On the Horizontal and Vertical Orientation task, his placement of the paper clips in a straight line equidistant from the two figures indicated mathematical reasoning characteristic of older concrete-operational children. On the Conservation of Area task, he seized on the idea of conservation of area immediately, but did not go beyond that to the idea of perimeter. I suspect that he would have figured this out if I had asked him to count the sides of each of the figures. However, his failure to figure out that the perimeter of the row of erasers was longer than that of the square figure was typical of concrete-operational children. On the Conservation of Displacement Volume task, he showed conservation, and even presented his analysis

of the problem in terms of "mass." This task is often not achieved until age 12 or older. On the Conservation of Substance task, Bill first gave a preoperational response, then on reflection gave a concrete-operational response. On the Part-Whole Relationship task, Bill demonstrated that he had completed the transition to the Concrete-Operational stage, since he had no problem with this task at all. In fact, he seemed to find it rather boring. On the Physical Causality, Animism, Artificialism task, Bill gave consistently physical explanations for physical phenomena, although he was careful to attribute the larger events to God as well as to physical causation. This, again, indicated functioning at at least the Concrete-Operational level. I had by this point begun to suspect that Bill was in transition to the Formal-Operations stage, so I presented him with a Syllogism task from that level. He solved two of the three syllogisms I presented with no problem, but he did not figure out the first one. On the Verbal Deductive Reasoning task, also at the Formal Operational level, the level of abstraction of the problem seemed to lose him. On the Hypothetical Reasoning task, another Formal Operational level task, he had no problem at all in formulating, in his own words, a rule for using angles of incidence in shooting pool. I wasn't sure how much of this to attribute to an inferred hypothetical reasoning ability, and how much to attribute to his direct experience in shooting pool.

Overall, I concluded that Bill had attained all of the Concrete-Operational level functions, and had begun the transition to the Formal-

Operational level. My initial assumption that he was Concrete-Operational, based on his age, was incorrect.

Case 5: Method

Subject. The subject for this series was a 12-year old female, the daughter of a university administrator. She will be called "Alice" in the following.

The Tasks. Initially, six tasks at the Formal-Operational level were presented, on the assumption that a 12-year old person would be functioning at the Formal-Operational level. These tasks are described in Appendix III. Because of Alice's performance on these tasks, two additional tasks from the Concrete-Operational level were administered, in an attempt to determine if she was still in a transitional stage from Concrete-Operational.

Task 1 - Proportional Reasoning. Here's this card, with this stick man on one side, and this one on the other side. HE'S BIGGER. Yes. And I've got two rulers, a "tall" one and a "short" one. So, I want you to measure this tall guy with this "tall" ruler. HERE? Yes, to the top of his head. IT'S 6. Ok, you might want to write that down. Now I want you to measure this short guy with the same ruler. ... 4. Ok, the short guy is 4 units tall, and the tall guy is 6 units tall. This time, I want you to measure the tall guy with the "short" ruler. HE'S 9. Ok. Now, how tall is that small stick man with this short ruler? Can you figure that out without actually measuring him? HMM. ... You know by the "tall" ruler that the measurements are 6 and 4, right? RIGHT. And with this "short" ruler the tall guy is 9 units

tall. How would you figure out how tall this short guy is without actually measuring? I DON'T KNOW. What do you know about this short guy already. HMM. ... It's not coming to you, how to work that out? NO. Want to try another one? YES.

Task 2 - Separation and Control of Variables. Now we need to make a pendulum. Do you know what a pendulum is? SWINGS BACK AND FORTH? Right. We'll make one out of this piece of string. I'll take some of this clay and put a weight on it. This is what I want you to figure out. Why does it go at that speed? How would you change it to make it go faster or slower? PUT SOME WEIGHT ON IT. Try it. I'LL JUST TAKE SOME CLAY OFF, FIRST. Whatever you want to do. ... Can you figure out a way to make it swing at some other speed? (Alice adds clay this time.) NOW WHAT DO I SAY, HOW COME IT SWINGS LIKE THAT? I want you to figure out how to change the speed that it swings at. TAKE SOME OF THE CLAY OFF. (She tries this again.) I THINK THAT'S WHAT IT IS. THE MORE YOU TAKE OFF.. CAUSE WHEN MORE OF IT'S ON THERE, IT WEIGHTS IT DOWN. (No real attempt yet to actually guage the speed. Alice is still trying to figure out what I want, rather than really thinking about the problem, as far as I can see.) Will that change the speed of it? YEAH, THE FIRST TIME IT DID. Try it again. (She swings it in different directions.) ... Is there anything else we can change about it? WE COULD TRY SHORTENING THE STRING. Do you want to try that? YES. (I pull some of the string up through my fingers.) Tell me when. THERE. ok. ... Do you want to shorten it some more and see what happens? YES. ... IT'S SWINGING FASTER,

ISN'T IT? More? YES.. NOW LONG AGAIN. Let's go back to where it was. ... So what do you think made it change its speed? I DON'T KNOW. ... SHORTEN IT AGAIN. ... So what do you think made it change its speed? WHAT DO YOU MEAN, CHANGE IT. If you want to change the speed of the pendulum, what do you have to change? THE LENGTH OF THE STRING. Ok.

Task 3 - Syllogism. I've got a few questions this time. Just suppose all teachers have purple hair. OK. John as purple hair. Therefore, John is a teacher. Is that true? JOHN? (I repeat the item.) Would you say that's true or not? THAT COULD BE TRUE. Would it always be true? NO. When wouldn't it be true? HE COULD CHANGE HIS HAIR WITHOUT BEING A TEACHER. Here's another one. Beetles eat elephants. This creature ate an elephant. Therefore, this creature must be a beetle. Would that always be true? NO. When would it be true. IF A BEETLE AT AN ELEPHANT. Here's another one that's more abstract. All B's are A's. All C's are B's. So, all A's are _____. What? I DON'T KNOW. Can you figure that out? WOULD BE A Z, OR B.. I DON'T KNOW. Let's try another one. Beetles eat only elephants and hamburgers. There is a fat, well-fed beetle in my pocket. The beetle in my pocket ate either an elephant or a hamburger. Would that be true? YES. Why would that be true? BECAUSE IF THAT'S ALL HE ATE, THEN HE WOULD HAVE HAD TO EAT AN ELEPHANT OR A HAMBURGER. Ok. here's another one. Bob is taller than Randolph. John is shorter than Randolph. Therefore, Bob is _____ than John. What would that be? (I repeat it.) ... THEREFORE, BOB IS TALLER THAN JOHN. How did you figure that

out? BECAUSE HE WAS TALLER THAN RANDOLPH, AND JOHN WAS SMALLER THAN RANDOLPH.

Task 4 - Verbal Deductive Reasoning. Here's another question for you. Bob has lighter hair than John. John has darker hair than Bruce. What is Bruce to Bob? Is he lighter haired, or darker, or what? Here, I'll let you look at it. ... What do you think it would be? ... YOU WOULD HAVE TO KNOW HOW DARK JOHN'S HAIR WAS. ... Read it over again, see if you can figure it out. LIGHTER HAIR. Would you say lighter? YES. How did you figure that out? I DON'T KNOW. IT'S JUST THAT JOHN HAD DARKER HAIR THAN BRUCE, AND BOB HAD LIGHTER HAIR THAN JOHN.

Task 5 - Hypothetical Reasoning. On this one, you get to do a little drawing. This is a pool table, and this is the ball. You want to hit this ball marked Y into one of these side pockets here, and you've got to hit it with the cue ball at X. See if you can figure out how you would do that. How would you hit the ball, to make it put this ball into that pocket there, or that pocket there? HIT IT, AND IT WILL PROBABLY BOUNCE OFF AND COME BACK. You can go ahead and draw it in there, what you think would happen. I DON'T KNOW. ... MAYBE THERE. I WOULD JUST HIT IT. Go ahead and draw it in. (In her sketch, she hits the ball at Y straight on with the cue ball. The ball Y hits the back-board, then describes a tight and impossible curve into a corner pocket.) I've got another one too. THIS ONE'S HITTING THAT ONE? Yes. I WOULD HIT IT THERE. How would you do it? ... LIKE THAT. (Alice draws this shot, a straight-in shot, accurately.) Here's another one. Did you ever

hit a pool ball, Alice? YES. ... What happens when you hit it straight? IT USUALLY BOUNCES OFF. Where is it going to go? PROBABLY, GO BACK UP IN HERE. Draw where you think it would go. WHERE I THINK IT WOULD GO? Yes, if you hit it just like that. (I indicate what I mean on the diagram.) IT WILL GO UP THERE. (She draws the ball hitting off the side at the angle of incidence quite accurately.) How are you going to get it into the pocket? IT'LL PROBABLY COME BACK AND GO IN. Do you think it will work that way? I DON'T KNOW. IT MIGHT. How do you think this one is going to work? Where's it going to go if you hit it like that? IF I HIT IT? Yes. IT'LL GO OVER THERE. MIGHT COME BACK AND GO IN. I DON'T KNOW. (Alice draws another impossible curve into the side pocket.) Could you make up any rule you would use in the future to figure out how to get the ball to go where you want it to go? YOU COULD JUST DRAW IT OUT. You mean draw a diagram like that? ... YOU WANT ME TO DRAW ONE LIKE THAT? I mean, if you were trying to explain it to someone, how would you tell them? HIT IT STRAIGHT, IF IT'S LIKE THAT. (She points to a diagram. I point to another one.) What if it's like that? HIT IT KINDA HARD, AND IT'LL PROBABLY BOUNCE OFF AND GO UP TO THE OTHER WALL.

Task 6 - Conservation of Volume. Here's one more. Do you know what volume is, how much space something takes up? YES. Ok, I've got this coffee cup here, and I want to know the volume of that coffee cup. Not how much it holds, but the actual volume of the cup itself. What would be some way I could figure that out? YOU MEAN JUST THE DISTANCE

AROUND, OR WHAT? No, how much room this whole cup takes up. How would I figure that out? MEASURE AROUND. What would be some other way to do that? I DON'T KNOW. How about if you had a goldfish, and you wanted to know how much space that fish took up in the fish tank, how would you figure that out? I WOULD MEASURE IT. Can you think of another way to do it? Maybe a simpler way? MEASURE THE SPACE AROUND IT, AND MEASURE IT, AND SUBTRACT IT. ... I MEAN, MEASURE THE FISH, AND MEASURE HOW BIG THE ROOM IS, AND SUBTRACT THE FISH VOLUME FROM THE ROOM VOLUME. What about a fish in a goldfish bowl? ... What would happen if you took the fish out of the water, what would happen to the water? TO THE WATER? IF I PICKED THE FISH UP? Yes, if you took the fish out and put him back into the water. Does that give you a clue to figuring out how much room it takes up? YOU WANT ME TO FIGURE OUT HOW MUCH ROOM IT TAKES UP WHEN YOU TAKE HIM OUT? Yes, and when you put him back. YOU WOULD DO THE SAME, EXCEPT THAT YOU WOULD DO THE FISH BOWL INSTEAD OF THE ROOM.

Task 7 - Conservation of Area (Concrete-Operational, see Appendix II.) I've got all these erasers here. I'm going to take four and set them out like that. (I form a square.) And I'm going to take four and set them out in a row like that. Ok, so I've got these four erasers in a block like that, and I've got these four laid out in a row. Do you think the distance around here, the perimeter, would be the same as the distance around here? NO. How did you figure that out? CAUSE THIS IS LONGER. How would you explain it in more detail? WELL, THAT'S LIKE A LITTLE BOX, AND THIS IS A LINE. IT TAKES UP MORE ROOM.

Task 8 - Part-Whole Relationship (Concrete-Operational, see Appendix II). Where is your town located. WHAT DO YOU MEAN? What state is it in? TEXAS. Is the state your town is in smaller or bigger or the same size as your town? MY STATE ... IS IT BIGGER THAN MY TOWN? Yes. YES. Are the people in your town also people in the state? YES. Where do the people of your state live? IN THE STATE. Are the people in Bowie County here called by the name of the state? NO. What are they called? THEY'RE NOT CALLED TEXAS COUNTY ARE THEY. I mean, what do you call people from Bowie County? Does that make sense? NO. Like, if somebody is from Ohio, you would say they are Ohioan? What do you call people from Texas? TEXANS. And what do you call people from Bowie County? BOWIEANS OR SOMETHING I GUESS. Somebody told me the other day that a San Franciscan is also a Californian. Would you agree with that? NO. What would they be? SAN FRANCISCAN? Could you be a San Franciscan and a Californian at the same time? NO. Which would you be. WHICH WOULD I BE? Which would you be if you were living in San Francisco? I DON'T KNOW WHAT YOU'D CALL HIM.. Maybe a San Franciscan? YES. Could I be a San Franciscan and a Californian at the same time? NO. How did you figure that out? WELL, YOU DON'T LIVE IN CALIFORNIA. Let's say I do, ok? YOU'D LIVE IN BOTH? Yes. WELL, THEN YOU'D BE BOTH, IF YOU LIVED IN BOTH.

Results for Case 5

On the Proportional Reasoning task, Alice made no attempt to apply the principles of proportion in solving the problem, even with prompting. She did not attain the Formal-Operational level on this task. On the

Separation and Control of Variables problem, she seemed to be preoccupied with figuring out what I was wanting her to do, rather than with figuring out a way to solve the problem. Her approach to this problem was unsystematic, although she eventually arrived at the correct answer with prompting. She appeared to be functioning at the Concrete-Operational level on this task. On the Syllogism task, she came up with valid answers on four out of the five problems, and her reasoning was logical. Additionally, she had no problem entertaining hypothetical situations such as beetles eating elephants, situations concrete-operational persons have trouble accepting because they are not realistic. On this task, Alice was functioning at the Formal-Operational level. She did not, however, succeed with the Verbal Deductive Reasoning task, even with prompting, indicating that she had not achieved the Formal-Operational level. On the Hypothetical Reasoning task, Alice indicated some understanding of the angle of incidence rule, but could not state it. She seemed quite confused on this task, except for situations where the pool ball would be hit straight on. My impression was that she did not achieve the Formal-Operational level on this task. On the Conservation of Volume task, Alice did not make the connection between volume of water displaced by the fish and the actual volume of the fish. She wanted to rely exclusively on measurement with some linear standard like a ruler. She did not indicate a grasp of conservation of volume on this task. I suspected by this point that she had begun the transition to the Formal-Operational level, but was just beginning that transition so I administered

two tasks at the Concrete-Operational level. On the Conservation of Area task, she produced the correct answer, but her responses indicated that she did not understand the reasoning behind her choice. On the Part-Whole Relationship task, she had a problem with accepting the proposition that I could be a hypothetical Californian who happened to actually live in Texas. Had I not had evidence from the Syllogism task that she was capable of entertaining hypotehtical situations, I would likely have assumed that she was not.

Overall, my impression is that Alice is Concrete-Operational, beginning the transition to the Formal-Operational stage. This contradicts my original assumption, based on her age, that she would be in the Formal-Operational stage.

Case 6: Method

Subject. The subject for this series of tasks was a 14-year old female, a businessperson's daughter. She will be called "Tilly" in the following description.

The Tasks. Six tasks at the Formal-Operational level were administered to Tilly on the assumption that at age 14 she would be functioning at the Formal-Operational level. These are described in Appendix III.

Task 1 - Proportional Reasoning. (I gave Tilly the two rulers used in this task, the "short" ruler and the "long" ruler, and had her measure both of the stick figures with the "long" ruler and the larger figure with the "short" one. I then asked her to figure out on the basis of that information how tall the short figure was in the units used on the "short" ruler. This first portion is not transcribed, as the taped

record is incomplete to this point.) SHOULD I JUST WRITE IT, OR FIGURE IT OUT? Well, just however you would figure it out. DO I NEED TO DO IT IN MY HEAD? No, you can write it out. I CAN FIGURE IT OUT IN MY HEAD? Any way you want to do it. OK. I ALREADY KNOW IT. 7 INCHES. How did you figure that out? ON THE LONG RULER IT'S FOUR, TWO MORE IS SIX. AND THAT WAS NINE. THIS ONE IS SEVEN, BECAUSE NINE MINUS TWO IS SEVEN. You mean you just took the difference (with the "long" ruler) and did that over there (with the short ruler) too? YES.

Task 2 - Separation and Control of Variables. This next one is where we do a thing with a pendulum. Do you know what a pendulum is, like in a grandfather clock, the thing that swings back and forth? YES. For a weight, we're going to use some of this clay. Now you can put on more clay for the weight, or you can take some off. You can push the pendulum harder if you want to, change anything about it you want to. What I want you to figure out how to do is find a way to make this pendulum swing at different speeds. I'm going to hold it right here for now, and you can start it swinging and see what it does. OK. DO YOU WANT ME TO CHANGE THE SPEEDS OR SOMETHING? Yes, I want you to figure out how to change the speed that it swings at. I MEAN DO I STOP IT AND THEN.. You can do anything you want. I'LL PULL OFF SOME CLAY. ... I'LL PUT SOME MORE CLAY ON. ... IT'S DONE. IT GOES AT DIFFERENT SPEEDS. WANT ME TO MAKE IT GO SOME MORE SPEEDS? Yes, make it go faster. (Tilly takes off some clay, and swings it in different directions and with different forces.) The thing I'm talking about is how long it

takes to get from one side to the other, not how far it travels. You know, how many times it goes back and forth every second, or whatever. OK. ... WHAT DO YOU WANT ME TO DO NOW? I want you to figure out how to make it go at different speeds. I'LL TAKE SOME MORE CLAY OFF. ... WHAT'S IT SUPPOSED TO DO? Does it look like it's going at different speeds to you? LET ME SEE. (She adds and removes clay, and swings it.) THEY LOOK LIKE DIFFERENT SPEEDS TO ME. They look like they're about the same speeds to me. Is there anything else you can change about it to make it go at a different speed? I DON'T KNOW. LET'S SEE, CHANGE DIRECTIONS? ... LOOKS LIKE IT'S GOING FASTER IN DIFFERENT DIRECTIONS. Still looks about the same to me. IT DOES? I wonder what else you could change about this thing. BRING THE STRING UP. Shorten it? YEP. ... IT'S GOING FASTER. YES, IT WENT FASTER WHEN YOU SHORTENED IT. So if I had a pendulum and I wanted to make it swing at a different speed, what would I do? SHORTEN THE STRING, OR MAKE IT LONGER. SHORTER IS FASTER.

Task 3 - Syllogism. Just suppose all teachers have purple hair. OK. John has purple hair. Therefore, John is a teacher. Would you say that's always true? NO. When would it be true? BECAUSE SOME PEOPLE COULD HAVE PURPLE HAIR BESIDES TEACHERS. Here's another one for you. Beetles eat elephants. This creature ate an elephant. This creature is a beetle. Would that always be true? NO. When would it be true? NEVER. A BEETLE COULDN'T EAT AN ELEPHANT. Well, let's just pretend that it can. OK. Now I've got this creature that ate an

elephant. Would that creature have to be a beetle? NO. When would it be a beetle? HUH? (I repeat the item.) When would that be true? ALL THE TIME, I GUESS. Ok, here's another one. All B's are A's. All C's are B's. So, all A's are ____? (She responds instantly.) ALL A'S ARE B'S. Ok. NO, C'S. Which is it? C'S. ... Beetles eat only elephants and hamburgers. There is a fat, well-fed beetle in my pocket. The beetle in my pocket ate either an elephant or a hamburger. HAMBURGER. Would that always be true? WHEN HE ATE HIM, I GUESS, I DON'T KNOW. Let's look at the whole thing. (I place the printed item before her.) THAT WOULD ALWAYS BE TRUE, YES. Ok, Bob is taller than Randolph. John is shorter than Randolph. Therefore, Bob is what to John. TALLER.

Task 4 - Verbal Deductive Reasoning. Here's another one about Bob. Bob has lighter hair than John. John has darker hair than Bruce. What is Bruce to Bob? Is he lighter-haired, or darker-haired, or what? BRUCE'S IS DARKER. Bruce has darker hair than Bob? YES.

Task 5 - Hypothetical Reasoning. This is a pool table from the top. That's the cue ball. ... Have you ever played pool? NO. Ok, this is the cue ball, and you hit it with a stick and it will go where you hit it. And that's the ball you want to put into this pocket over here, or this pocket over here, a side pocket. Now, how would you hit this ball with this ball to make it go into one of those side pockets? HOW? Yes, you can draw a little diagram on there. IN OTHER WORDS, YOU'D HAVE TO HIT THAT BALL WITH.. Yes. Well, you're

shooting with this one, and you're hitting this one, and you want it to go into either one of these pockets. How would you do it? WANT ME TO DRAW IT OUT? Sure, just draw it right on there. (Tilly draws a bank shot, the first angle of which is a true incident angle and the second is impossible.) RIGHT DOWN THE SIDE. And where would this ball go then? THERE. Ok, here's another one. How would you hit this ball to make it go into that pocket? (This is a straight-in shot, and she draws it accurately.) You're going to kind of hit it off the side there? YES. What about this one? (Again a straight shot, which she draws accurately.) See if you can find another way, is there any other way you could possible do that? YOU COULD GO LIKE THAT OR LIKE THAT.. I DON'T KNOW.. THAT WAY, AND THAT WAY. If you hit a ball straight on, how will it move? STRAIGHT. What if you hit it at a 45 degree angle? Do you know what a 45 degree angle is? NO. (I draw one for her.) Now if I hit this ball a little off to the side like this, which way is it going to go? THAT WAY. (She points accurately.) Ok. Now can you compare what happens when you hit the ball off the wall with what happens when you just hit the ball directly? Does that make sense to you? YES. Now, what I'd like you to do is figure out how you would explain that to somebody, how to make the ball go where you want it to go when you hit it off the wall. I'M GONNA HIT IT OFF THIS WALL AND MAKE IT GO OVER THERE. How would you explain to them how to figure it out? Is there some kind of a general rule or something? WELL, IF YOU HIT IT THERE LIKE THAT, IT

WOULD GO IN THAT SIDE POCKET.

Task 6 - Conservation of Volume. Here's another one. I want to know how much space this pen takes up. Now, what's some way I could figure that out, without actually taking a ruler and measuring it? How would I figure out how much space it takes up? Can you think of a way to do that? MEASURE IT WITH A RULER, I GUESS. Let's say you couldn't measure it that way. WEIGH IT. You could do that. Let's say we took this pen and put it in a jug of water. What do you think would happen. IT WOULD RISE.. NO IT WOULDN'T.. YES IT WOULD, IT WOULD RISE. OR MAYBE IT WOULD. I DON'T KNOW. Well, let's say it's a real heavy pen. IT WOULD RISE. YOU COULD STICK IT IN A BOWL OF WATER AND WATCH HOW IT ROSE.

Results for Case 6

Tilly's responses on the Proportional Reasoning task were not correct, but she did appear to be using a rationale for her answer other than simply guessing. There is evidence from this task that she has at least begun a transition to the Formal-Operational level. On the Separation and Control of Variables task, Tilly eventually arrived at the correct answer, with extensive prompting. As with Alice in Case 5, she seemed to be preoccupied with figuring out what I was wanting from her rather than with solving the problem. I suspect that she would not have solved this problem without extensive prompting. On the Syllogism task, she got a correct answer on two of the four items, but was unable to clarify the procedure she used in arriving

at her answers. Also, she had some difficulty in accepting hypothetical situations which had, for example, beetles eating elephants. However, she did go along with these suppositions when asked to. On the Verbal Deductive Reasoning task, she quickly reached an incorrect conclusion and seemed to be satisfied with her response. I suspect that here, as in the other tasks, she was more concerned with producing an answer I would accept than with solving the problem. On the Hypothetical Reasoning task, she was able to begin to formulate the principle of angles of incidence, but not to carry it out to a complete formulation. On the Conservation of Volume task, however, she did grasp the principle of how one could measure the volume of an object by immersing it in water and observing how much the water rose, a problem Alice in Case 5 could not solve.

Overall, my impression is that Tilly was functioning largely at the Concrete-Operational level, with some transition underway to the Formal-Operational level. As with Alice in Case 5, my assumption that Tilly would be at the Formal-Operational level, which was based on her age (14), was incorrect.

Discussion

In retrospect, I found that administering the Piagetian tasks to Preoperational and Concrete-Operational children, at least those I worked with, was both charming and illuminating, while working with the children presumed to be in the Formal-Operational stage was rather taxing. The younger children did not seem to be in the least

concerned with what I wanted from them. Rather, they seemed to dig into the problems I was presenting in a spirit of curiosity and what appeared to be fascination. On the other hand, Alice and Tilly, aged 12 and 14 respectively, seemed to be preoccupied with what I wanted from them. Rather than dealing with the tasks, they seemed to be dealing with me, trying to get at how I wanted them to perform. The non-directive feedback I was giving them seemed to produce and maintain a state of confusion. I suspect that Alice and Tilly, who are both performing well in school, are memorizers.

I am not informed enough in Piagetian theory to judge its worth, but in actually applying Piagetian principles in the testing sessions, I was convinced of the validity of the theoretical formulations of stages of development through the Preoperational and the Concrete-Operational levels. My direct observations of the children I worked with were certainly in line with what I would have expected from the theoretical model.

I must still entertain reservations about Piaget's formulation of the Formal-Operational stage. Perhaps the theory is inadequate at this level in describing cognitive development. Sund (1976) sounds an alarm about possible inadequacies in our educational practices which may be making it difficult for children to achieve Formal-Operational abilities. (p. 75-80) It is possible that a

straw man is being set up here, if Piaget's formulation is inadequate for dealing with this stage of cognitive development. Sund cites research, for example, (p. 75) to the effect that students entering freshman courses in physics are predominately Formal-Operational thinkers, and interprets this to mean that students who are not functioning at this level are avoiding such courses because they feel intellectually incapable of dealing with the content. This may well be, but I wonder if all intellectually competent students would even be interested in taking courses in physics.

It may well be that some individuals reach the Formal-Operational stage well past age 15, or not at all, and still function with a good deal of intellectual competence in areas outside the realm of formal mathematical and logical thought. It may be, too, that those individuals function more effectively in areas of cognitive ability not encompassed in the Piagetian framework.

One strong impression, on completing this modest study, is that Piagetian principles could be applied to very good effect to teaching in the grades, particularly grades K through 7, and to raising children in the home. I think it would be service to the very young to inform parents and educators of the futility of teaching Concrete-Operational material to Preoperational children, particularly if corroborating research bears out this hypothesis.

Personally, I am sure that I will be interacting with children from now on rather differently than I have in the past. I have

(though I am loath to admit it in light of what has gone before) tended to deal with children as miniature, though rather inadequately informed, adults. Even a passing acquaintance with Piagetian principles has not only brought me closer to the children around me, but has also put me in touch again with some of the mysteries and wonders of my own childhood. I would recommend a study of Piaget to anyone.

References

Lefrancois, G.R. Psychological theories and human learning: Kongor's report. Monterey, California/Brooks-Cole Publishing Co., 1972.

Sund, R.B. Piaget for educators. Columbus, Ohio/Charles E. Merrill Publishing Co., 1976.

APPENDIX I

Preoperational Tasks used in this Report

Task 1 - Multiple Inclusion

Materials. Sets of triangles and rectangles, in two sizes, cut from heavy paper of orange and blue color. Two small boxes to put the cutouts into in sorting.

Procedure. Ask the child to put all the shapes that go together in one box and all the other shapes in the other box. After this is done, put all the shapes back on the table and ask the child to group the objects another way.

Discussion. The child is likely to sort the objects by shape or by color. Some may change their approach halfway through. This task requires multiple classification ability. Children four or five years old should have little difficulty with this task.

Task 2 - Class Inclusion

Materials: Two apples and ten grapes.

Procedure. Lay the two apples and ten grapes out in a row before the child. Ask "In what way are these alike? What do you call them?" If the child does not offer the broad class "fruit," explain that they are all fruit. Be sure he/she understands what the word means. Then ask, "Are there more grapes than fruit? If I took the fruit and you took the grapes, would I have more, or would you? How would you be able to prove who has more?"

Discussion. Younger preoperational children will tend to be overwhealmed by the number of grapes, and will miss the distinction between

the large class "fruit" and the subclass "grapes." They will normally respond that they will come out ahead if they get the grapes and you get the fruit.

Task 3 - Conservation Task

Materials. A rubber band.

Procedure. Show the child the rubber band. Let him/her handle it. Stretch the rubber band and ask "Do I have more rubber band than I had before I stretched it, the same amount of rubber band, or less rubber band? Why is that?"

Discussion: Preoperational children do not conserve; in this case, they do not conserve mass. They will assume that since the rubber is larger when it is stretched, there must be more rubber band.

Task 4 - Conservation of Substance

Materials. Modeling clay.

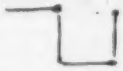
Procedure. Make two round balls of clay of equal size. Ask the child if the two balls are of equal size, and if he/she doesn't think so, work with them until the child agrees that they're the same. Then roll one of the balls into a cylinder or flatten it. Ask the child if the new shape has more clay, the same amount of clay, or less clay than the ball of clay. Ask also why that is. Tell the child "The other day a little girl told me that there was more in the rolled out clay. How would you prove that she was right or wrong?"

Discussion. Preoperational children do not conserve substance. They will assume that the flattened or rolled-out clay has more clay in it.

Task 5 - One-to-One Correspondence

Materials. Eight match sticks.

Procedure. Make two straight rows of four matches each. Ask the child "Is each of these lines the same? Why?" Then, leave one row of matches as it is and alter the other one as shown below.



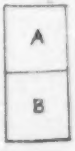
Ask "Are the two lines the same now? Why? Is there more, less, or the same number of matches in each line? Why?"

Discussion. Preoperational children will say that the altered row has fewer matches in it, because it is shorter; i.e., they cannot do a one-to-one correspondence task.

Task 6 - Structure, Transitional.

Materials. Two, three by three inch squares of card stock, with the letter "A" printed on one and the letter "B" printed on the other. Paper and pencil.

Procedure. Place the two squares so the A square is directly above the B square, as shown:

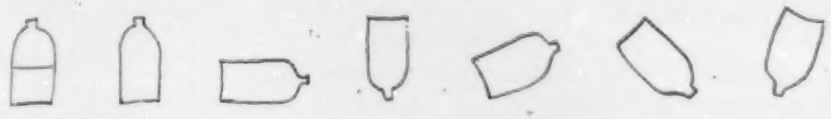


Ask the child to draw what he/she sees. If he/she does not draw it correctly, go on to the next task, as the child has not reached transition to the Concrete-Operational level. If he/she can do it, ask "How would the square with the A on it look if it were slid a little bit to the right of B, but were still on top of it?" Have the child

draw it. Then slide it over, and have him/her draw it again.

Discussion. By age 7, about 77% can draw the modified figure without seeing it. By age 5½, only 76% can even make an accurate copy of the modified figure when looking at it.

Materials. A clear glass bottle, a diagram similar to that shown here, and a pencil.



Procedure. Tip the bottle in several positions, showing the child what happens to the water in the bottle. Then ask the child to draw in the water line on the chart.

Discussion. Early preoperational children will scribble all over the bottle. Later preoperational children will draw the water lines parallel to the bottom of the bottle. Preoperational children in transition to Concrete-Operational thinking will draw the liquid obliquely toward the opening. Children around ages 9 or 10 and older will draw it correctly.

Task 8 - Artificialism.

Procedure. Ask the child "Who made the sun? Who made the stars? Who made the moon? Who made the mountains? Who made the space ship that went to the moon? Who made waterfalls, lakes, waves on the ocean?"

Discussion. Preoperational children will ascribe natural phenomena to the efforts of humans or of God (where God is a big person in the sky).

Task 9 - Construction of 2-Dimensional Space

Materials. Two pieces of blank 8½x11 paper and a pencil. Scissors,

a ruler, and a string.

Procedure. Place a dot on one piece of paper about halfway from the top and halfway from the center. Give the child all the materials and suggest that he/she can use any of them that they want to. Ask "How well can you place a dot on the blank sheet of paper so it's in the same location as the one on the other sheet?"

Discussion. Young preoperational children will guess where the dot should go, without measuring. More advanced preoperational children will use measurement, but usually in only one dimension. By around age 9, children will make a two dimensional measurement, both from the top and the side of the paper.

Task 10 - Seriation.

Materials. A deck of 10 cards cut from card stock, decreasing evenly in size from one card to the next. Draw stick figures or some other figure on the cards.

Procedure. Place the largest and the smallest card before the child, with space between them sufficient for the rest of the cards. Ask the child to place the rest of the cards in order the way he/she thinks they should go.

Discussion. This task is appropriate for both older preoperational children and for concrete-operational children. Children around age 8 or 9 will often be able to sort the cards into ascending or descending order.

APPENDIX II

Concrete-Operational Tasks used in this Report

Task 1 - Seriation

Materials. A deck of 10 cards cut from card stock, decreasing evenly in size from one card to the next. Draw stick figures or some other figure on the cards.

Procedure. Place the largest and the smallest card before the child, with space between them sufficient for the rest of the cards. Ask the child to place the rest of the cards in order they way he/she thinks they should go.

Discussion. This task is appropriate for both older preoperational children and for concrete-operational children. Children around age 8 or 9 will often be able to sort the cards into ascending or descending order.

Task 2 - Correspondence

Materials. A glass bowl and a small glass, and about 20 pennies.

Procedure. Place one penny in the bowl and one in the glass. Do this several times, saying each time "I'm putting one penny in the bowl and one in the glass." When there are plenty of pennies in each, ask "Do I have more pennies in the bowl or in the glass? Why do you think so?" If the child does not answer correctly, have him/her count the pennies in each container, and ask the questions again.

Discussion. This task will determine if the child has achieved the concrete-operational ability to do one-to-one correspondence.

Task 3 - Horizontal and Vertical Orientation.

Materials. Two cards, with a stick person on each one, and five paper clips.

Procedure. Place the two cards some distance apart on the table. Ask the child to place the paper clips so they are halfway between the one stick figure, the "teacher," and the other figure, the "student."

Discussion. The child should place the clips in a relatively straight line. Older concrete-operational children will probably place the clips in a very straight line.

Task 4 - Conservation of Area.

Materials. Eight square rubber erasers.

Procedure. Place four of the erasers in a square figure, and make a straight row out of the other four. Ask the child if it is further around the square or the long row. Ask how he/she figured it out.

Discussion. By about age 8 to 10, children will usually conserve area, but will think if the area is the same the perimeter must be the same. If the child cannot figure it out, have him/her count the sides and ask the questions again.

Task 5 - Conservation of Displacement Volume.

Materials. Modeling clay, 2 clear glass tumblers, and a marker.

Procedure. Fill the tumblers 3/4 full of water, and mark the water line in each with the marker. Show the child what you are doing. Roll the modeling clay into two balls, and work with the balls until the child says they are the same size. Then, flatten one of the balls out. Ask

the child to mark where he/she thinks the water is going to go in the glass when the ball of clay is put in one, and the flattened piece is put in the other. Put the clay in and talk about what happens.

Discussion. Children who think the flattened clay will displace more or less water than the ball are not conserving displacement volume. This task is not usually achieved until about age 12.

Task 6 - Conservation of Substance

Materials. Some pieces of popcorn, popped and unpopped.

Procedure. Show the child some popped and unpopped popcorn. Ask "Do you think there is more corn after it is popped than before it is popped, or is it the same, or what?" Ask the child to explain how he/she figured that out.

Discussion. Preoperational children will assume that there is more corn after it is popped, because the volume is larger. Concrete-operational children will generally conserve, stating that the amount of corn is the same.

Task 7 - Part-Whole Relationship

Procedure. Ask the child "Where is your town located? Is the state your town is in bigger, smaller, or the same size as the town? Are the people in your town also people in the state? Where do the people of the state live?" Draw a rough outline map of the state and ask the child to draw in where his/her county is. Ask "Are the people in this county called by the name of the state? Why is that? The other day a boy told me that a Texarkanian is also a Texan. What would you tell that boy? How would you prove it?"

Discussion. This task indicates a transition to Concrete-Operational level thinking, if the child can separate the idea of membership in the town from membership in the state and work with the two ideas together.

Task 8 - Physical Causality, Animism, Artificialism

Procedure. Ask questions about the following and how they were formed: Lakes, wind, stars, floating objects, etc.

1. Stars: "What are stars? Where do they come from? How were they made? Why do you think that?"

2. Lakes: "When did you see a big lake? What did it look like? How was it formed? What is a lake made of? What will the lake be like in 100 years from now? Is a lake alive? Why do you think that?"

3. Wind: "Where does the wind come from? When it isn't here, where is it? Where did it come from in the first place? Where is it now? What makes up wind? Is the wind alive? Why do you think that?"

4. Floating Objects: "What floats on water? Why do these things float? Do they like to float? Why do things sink in the water?"

Discussion. Young children often give animistic or magical or artificialistic explanations of things in their environment. As children move into the Concrete-Operational level, around age 7 or 8, they begin attributing physical phenomena to physical causality.

APPENDIX III

Formal-Operational Tasks used in this Report

Task 1 - Proportional Reasoning

Materials. One 8½X11 card with a stick figure on each side, one of them 2/3 of the height of the other and two "rulers," graduated proportional to the different figure sizes (i.e., the units on the two rulers are different but proportional to each other in the same relationship as that between the two figures). Label the ruler with the longer units the "tall" ruler and the other the "short" ruler.

Procedure. Have the child measure and note the height of each of the stick figures with the "long" ruler. Then, have him/her measure the tall figure only with the "short" ruler, and note the result. Ask "How tall does the small stick person measure, in terms of the "short" ruler?"

Discussion. The child has achieved this task when he/she can figure out the height of the short stick figure in terms of "short" ruler units using proportions. A simple guess will not suffice. At any rate, you should have the student explain how he/she derived the answer.

Task 2 - Separation and Control of Variables

Materials. String and modeling clay.

Procedure. Put some clay on the end of the string and hold it to form a pendulum with a length of about three feet. Ask the child to figure out how to change the speed the pendulum swings at.

Discussion. Success on this task is figuring out that the one variable that changes the speed of the pendulum is the length of the string. The child's justification must include the idea of holding the other variables (weight of clay, height of drop) constant while altering the string length. Formal thinking involves separating and controlling one variable at a time in solving the problem. Pre-operational children will play with the apparatus but will not produce a plan of approach to the problem. Concrete-Operational level children may come up with the correct answer but will not separate and control the variables systematically.

Task 3 - Syllogism

Procedure. Present the child with the series of syllogisms below and ask if they are valid arguments. Also, ask for a justification of answers.

1. Just suppose all teachers have purple hair. John has purple hair. Therefore, John is a teacher.

2. Beetles eat elephants. This creature ate an elephant. This creature is a beetle.

3. All B's are A's. All C's are B's. So all A's are _____.

4. Beetles eat only elephants and hamburgers. There is a fat, well-fed beetle in my pocket. The beetle in my pocket ate either an elephant or a hamburger.

5. Bob is taller than Randolph. John is shorter than Randolph. Therefore, Bob is _____ than John?

Discussion. The child has succeeded on this task when he/she can judge the arguments accurately as valid or invalid, and can show a logical justification for the answers. In addition, Concrete-Operational level children will not accept hypothetical situations such as beetles eating elephants, while Formal-Operational individuals will.

Task 4 - Verbal Deductive Reasoning

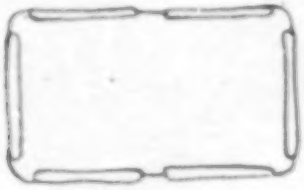
Procedure. Ask the following question:

"Bob has lighter hair than Bruce. John is darker-haired than Bruce. What is Bruce to Bob?"

Discussion. This task is achieved when the child indicates that from the information given, Bruce could have lighter hair or darker hair than Bob.

Task 5 - Hypothetical Reasoning

Materials. A diagram of a pool table similar to that shown here:



Procedure. Show the child the diagram of the pool table, and ask him/her to trace how he/she would hit the ball so that it would hit ball x in each of the different positions and make it go into one or the corner pockets. After the child has drawn several different ways to do that, ask if he/she can describe any rule that could be used in the future in making shots. You may have to help with this, by asking

things like: "If you hit the ball straight on, how will it move? If you hit it at a 45 degree angle, how will it move?" (Show the child what a 45 degree angle is if he/she doesn't know.)

Discussion. The essential idea here is that a Formal-Operational level child will, one way or another, state that the angle of incidence equals the angle of reflection. Be sure this formulation is not memorized by checking it out with the child.

Task 6 - Conservation of Volume

Procedure. Ask the child "How would you measure the volume of this pen? (or coffee cup, or some other object) Why?" If the child cannot figure out what you are after, ask him/her what would happen if the object were placed in a clear glass container full of water.

Discussion. Children who understand the idea of conservation of volume will suggest putting the object in a container of water and either observing the change in the water level as an indication of volume, or of measuring the water that is displaced from a full container when the object is put in it.

ACKNOWLEDGEMENT: All of the tasks described in the three Appendices are adapted from Sund, R. B. Piaget for educators. Columbus, Ohio/ Charles E. Merrill Publishing Co., 1976. Pp. 122-150.